SiC walls from a core-integration perspective in DIII-D

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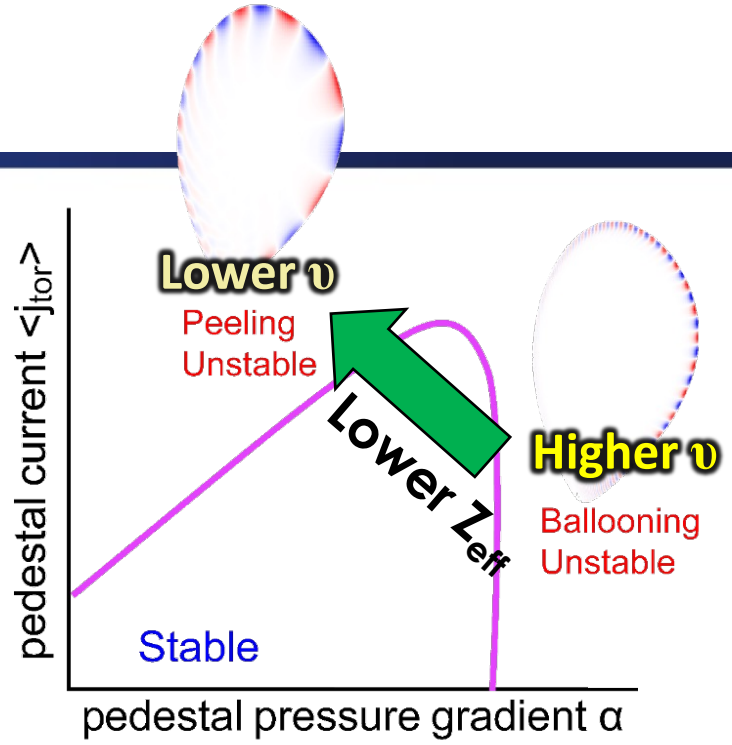
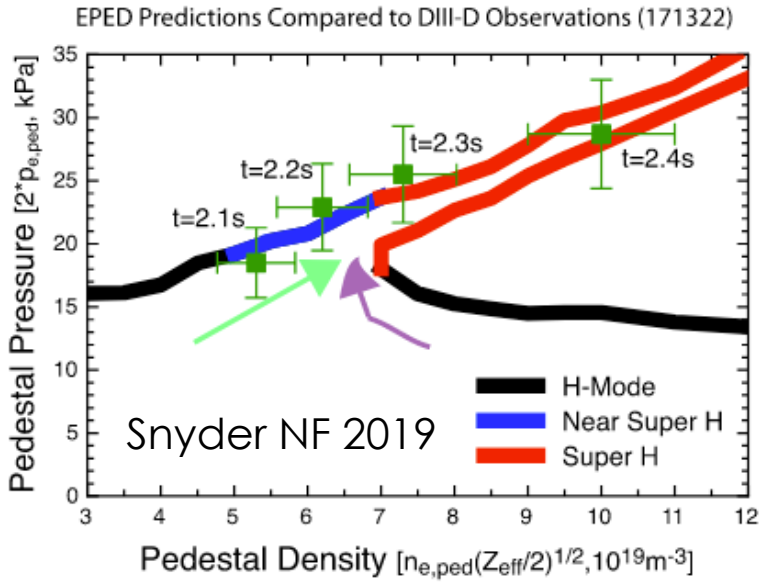
Figure of Merit: Lowering Z_{eff}

- $\upsilon_i^* \sim Z_{eff}^4$ and $\upsilon_e^* \sim Z_{eff}$ Sauter PoP 1999
- **$Z_{eff} \downarrow \rightarrow$ higher bootstrap current**
  - Easier to avoid ballooning limits and access reactor-relevant peeling-limited pedestals
  - Important for Super H-Mode and SVR project
- **Less intrinsic impurities allows greater control over Z_{eff} with extrinsic (puffed) impurities**
  - More control over Z_{eff} = easier to navigate into Super H-Mode channel





(b)

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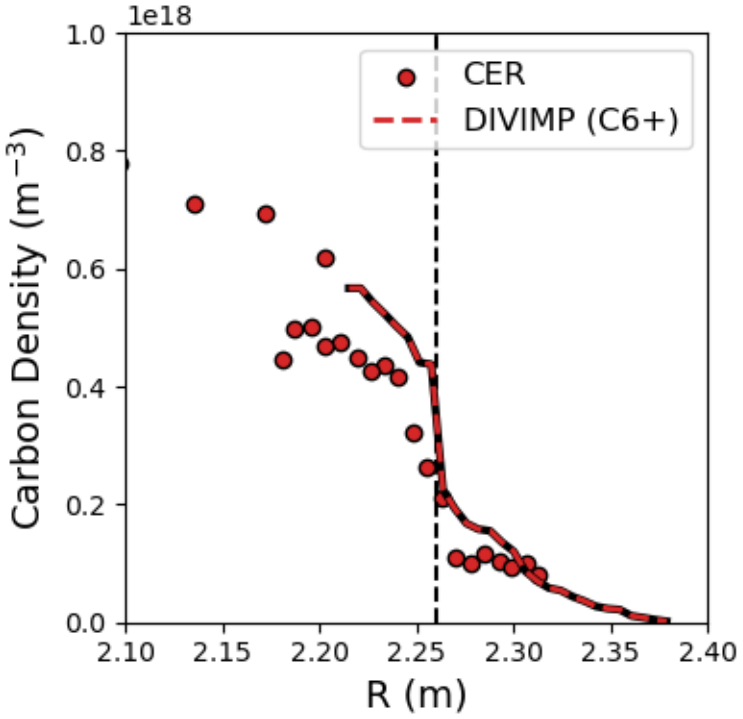
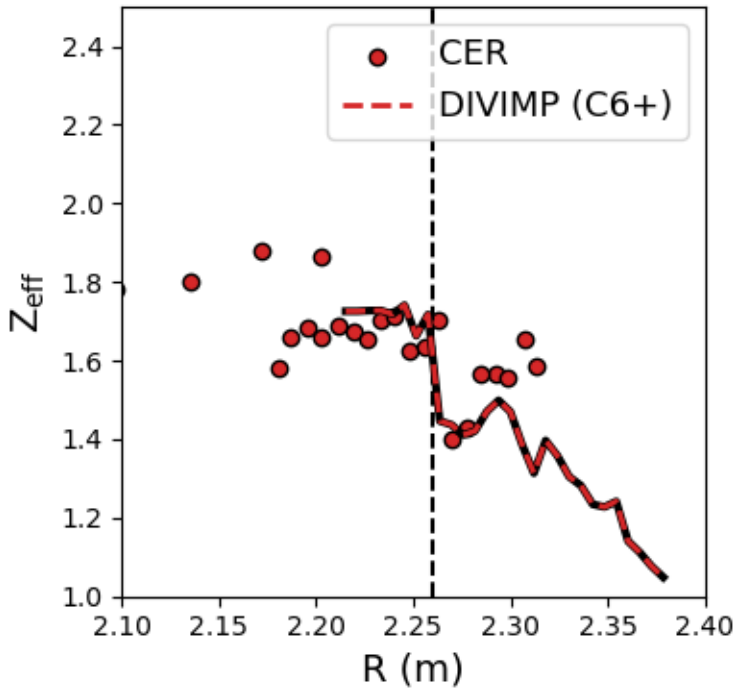
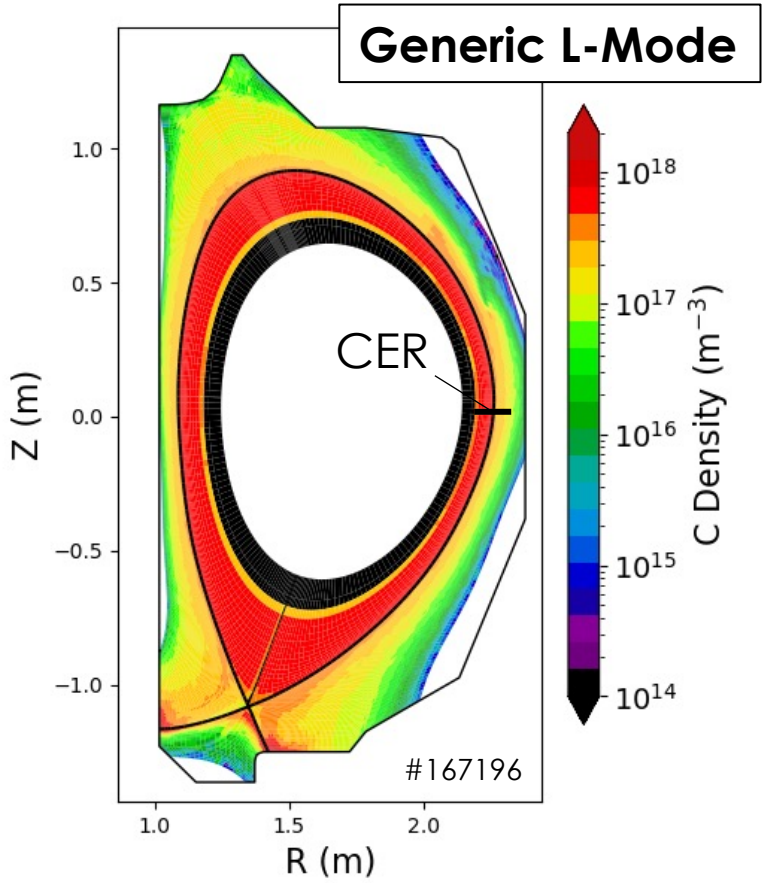
DIVIMP simulations predict overall decrease in Z_{eff}

- **Step 1: Constrain graphite wall only case against CER data to instill confidence in transport coefficients**
  - Comparing as if C6+ is only impurity since that's what CER assumes



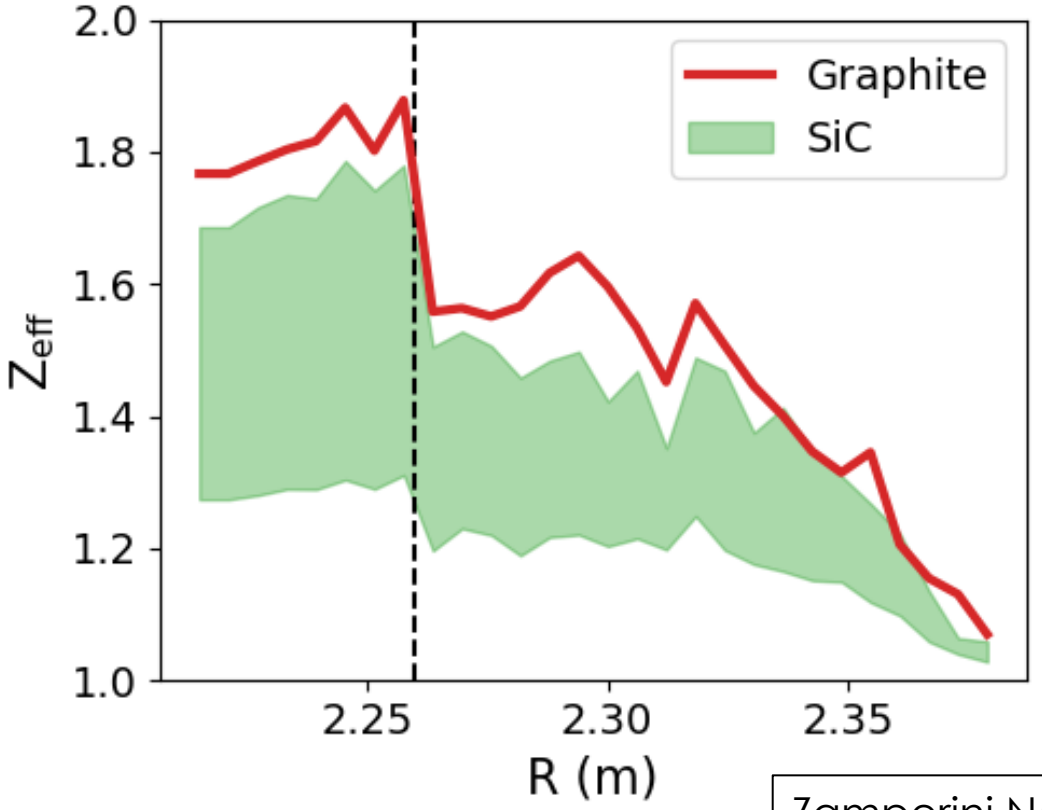




Zamperini NME 2023

DIVIMP simulations predict overall decrease in Z_{eff}

- **Step 2: Repeat simulation with SiC walls**
  - Vary carbon and silicon plasma content to give range of possibilities for sputtering (f_C = 0.2-2%, f_{Si} = f_C / 10)



Zamperini NME 2023

- **DIVIMP simulations show SiC could lower Z_{eff} relative to graphite**

- **Self-conditioning effect expected to <u>further lower</u> Z_{eff} due to oxygen gettering**

Next topic

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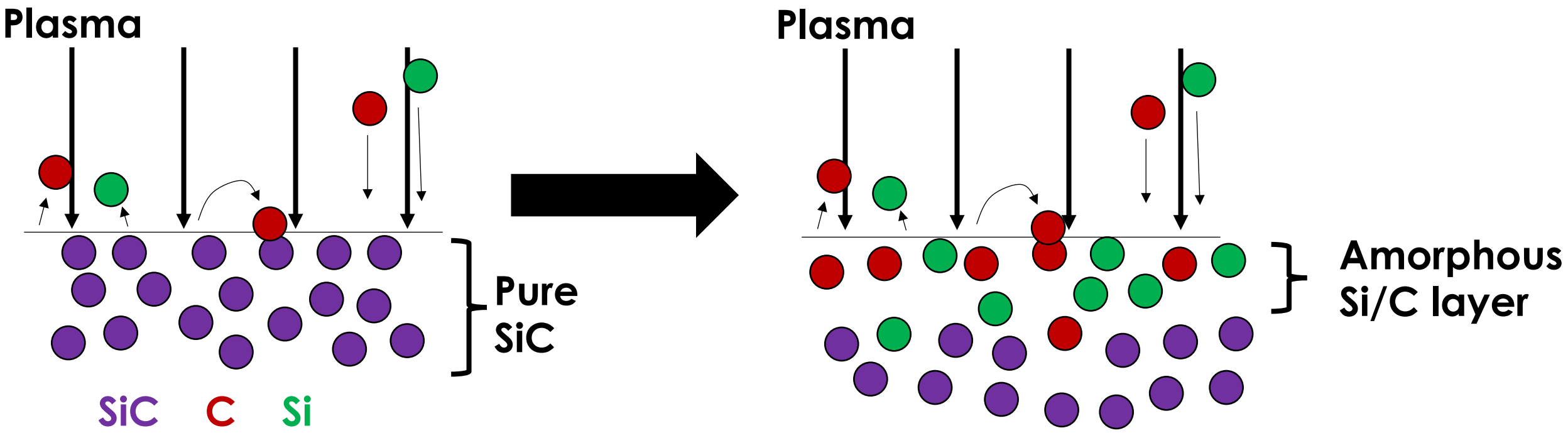
SiC walls may be expected to "self-condition"

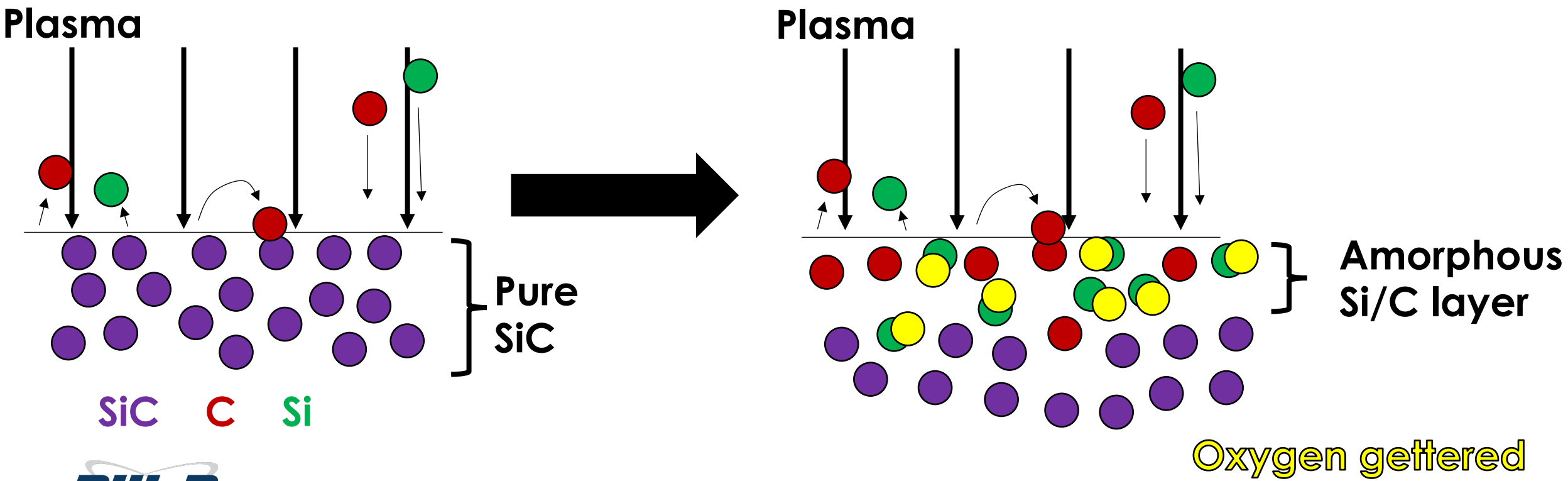
- SiC surface will quickly amorphize

Sizyuk APS 2023



SiC walls may be expected to "self-condition"

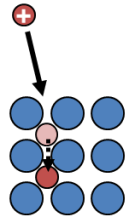
- **SiC surface will quickly amorphize** Sizyuk APS 2023
- **Surface composition identical to siliconization with graphite walls**
  - Expect similar conditioning benefits, dangerous silane not needed (safer!)



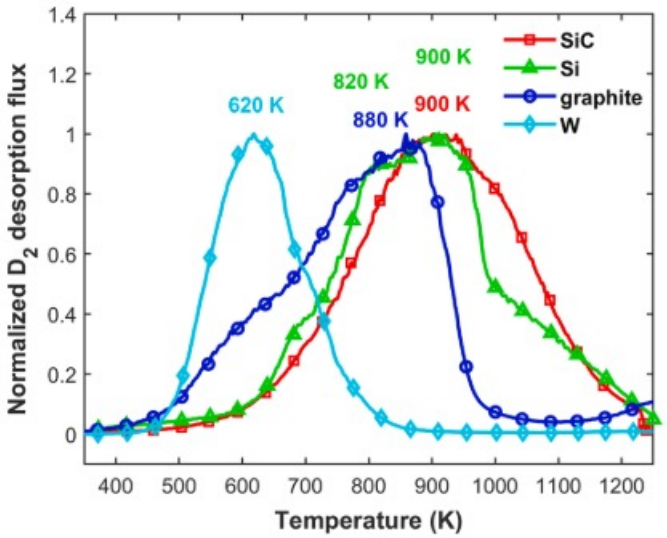
Backup Slides

Silicon carbide traps hydrogen at high temperatures, requiring high surface temperatures to slow accumulation rate

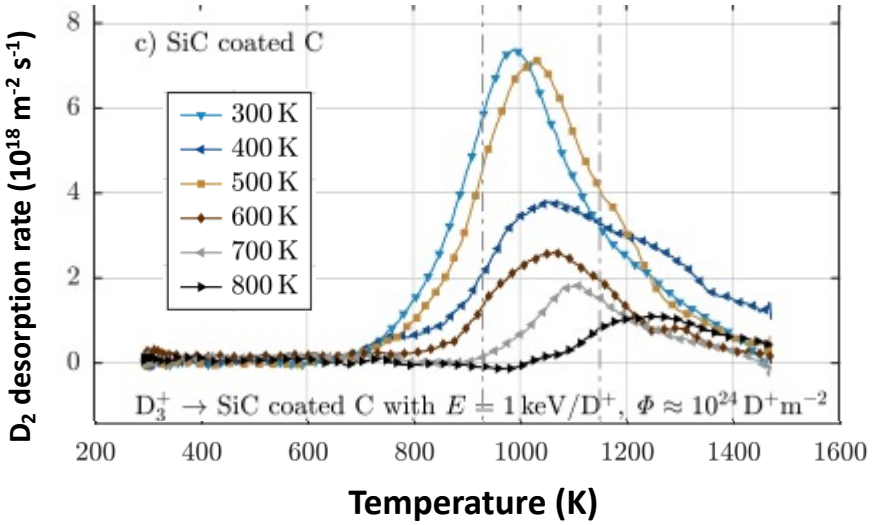
- D is retained in higher temperature traps in SiC (~900 K) than in W (~600 K)
- Increasing surface temperature during exposure yielded 5-6× decrease in D retention
- Si surface enrichment at low impact energies may influence long-term hydrogen buildup



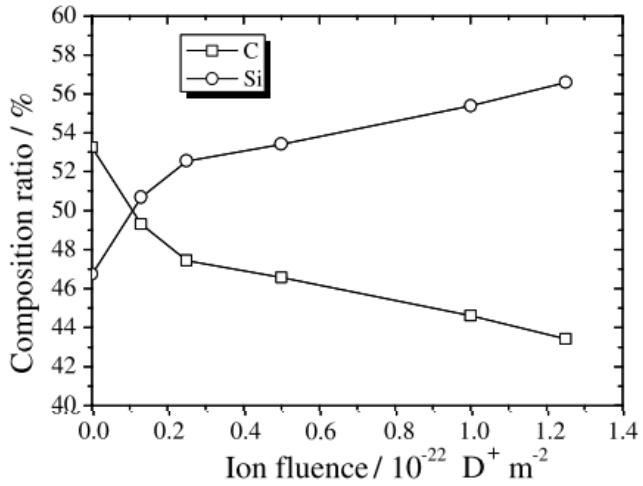
Retention (implantation)

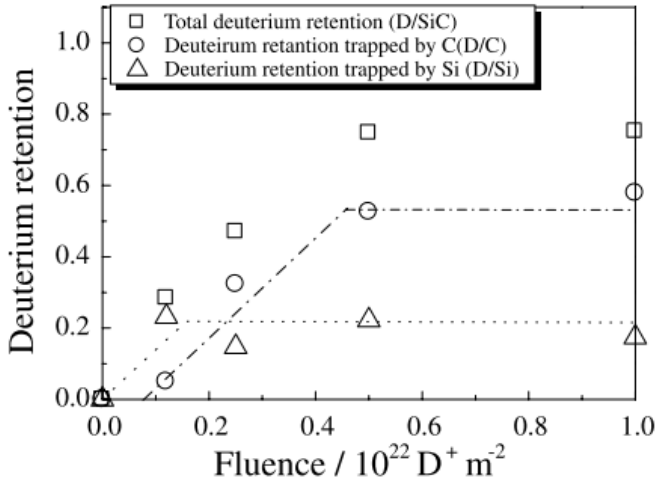


Sinclair et al., Nucl. Mat. Energy, 2021



Koller et al., Nucl. Mat. Energy, 2019

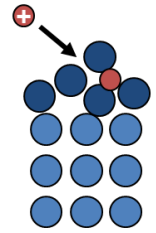


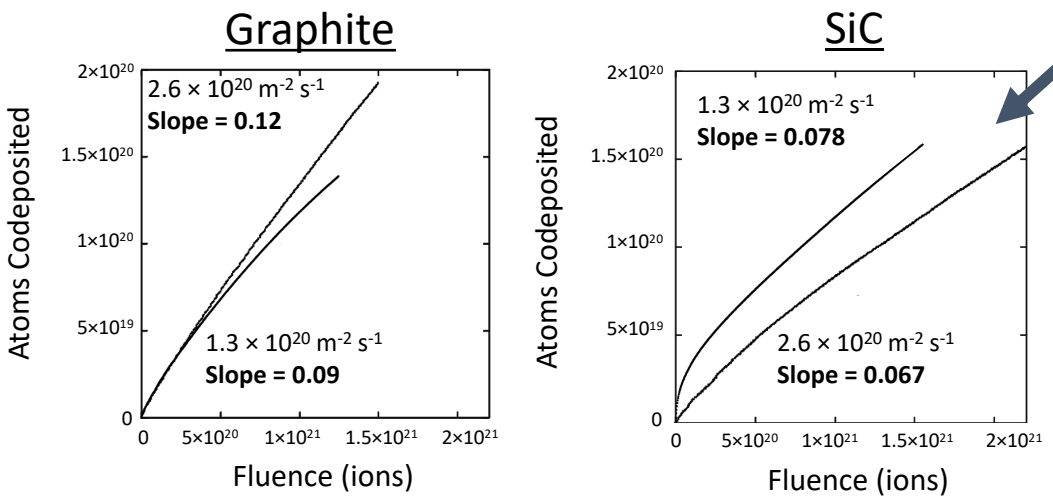


Oya et al., J. Nucl. Mat., 2005

Difference in co-deposition between C and SiC is unclear; high temperatures reduce co-deposit growth rate

- **Co-deposition refers to trapping of H/D/T in re-deposited material**
  - high T co-deposition in C cited as primary reason for dismissal as FPP-relevant PFM
- **Two studies in last 20 years present conflicting results on difference in co-deposition between graphite and SiC**
  - role of co-deposit composition is unclear

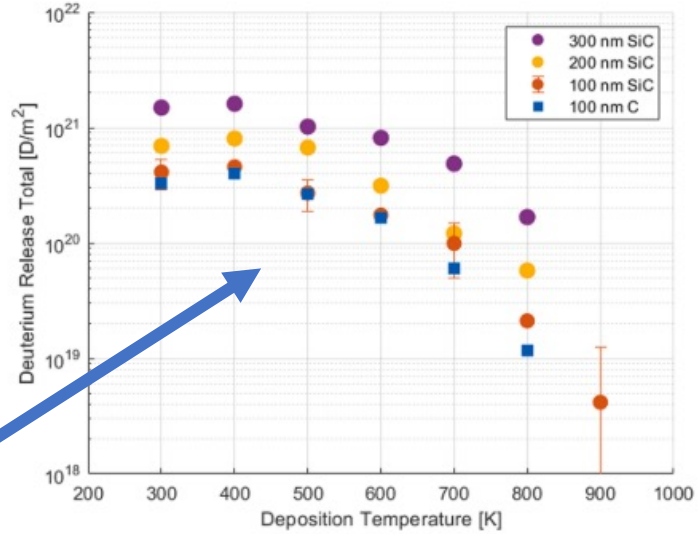




Causey, J. Nucl. Mat., 2003

Co-deposition probability is 1/3 lower in SiC vs. graphite

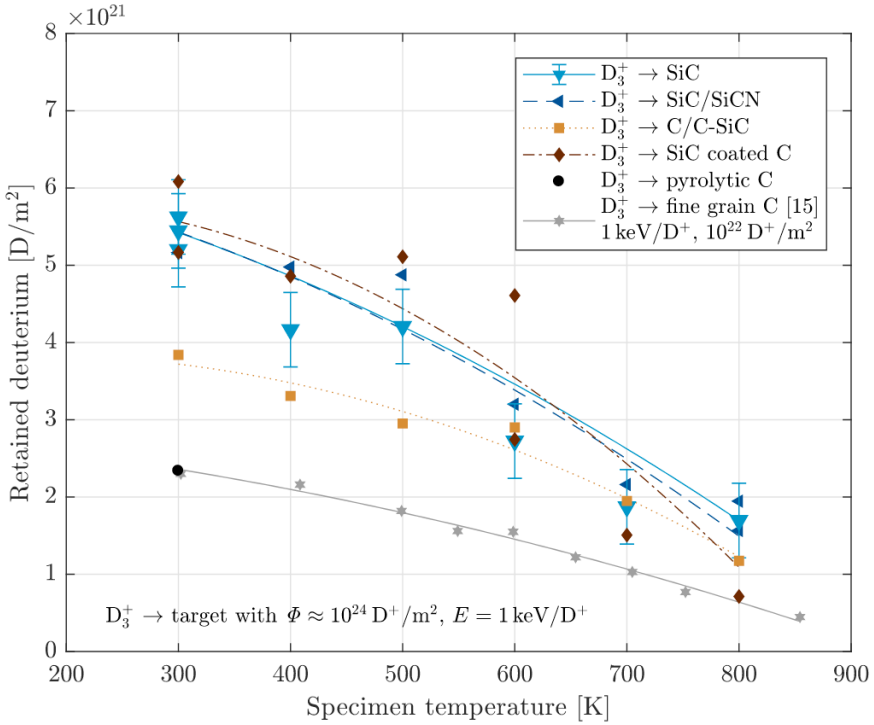
2× higher D retention in SiC co-deposits vs. C co-deposits at 800 K



Lantaigne et al., Nucl. Mat. Ener., 2022

Tritium retention is unresolved issue

Hydrogen retention in SiC slightly higher compared to graphite



Koller NME 2019

Mitigation strategies

- **Oxygen baking?**
  - Presence of Si in Si/C deposits severely hindered hydrogen removal
  - Likewise for B in B/C deposits
- **Operate with hot walls >500-800 °C**

Cruse *In Review*

Shahid FST 2021

This is the biggest drawback of SiC (and C) as a wall material

High-Z may not fare any better due to large amounts of injected powder…

Stangeby PPCF 2022

Various talks at PSI 2024

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SiC walls could simplify blanket designs

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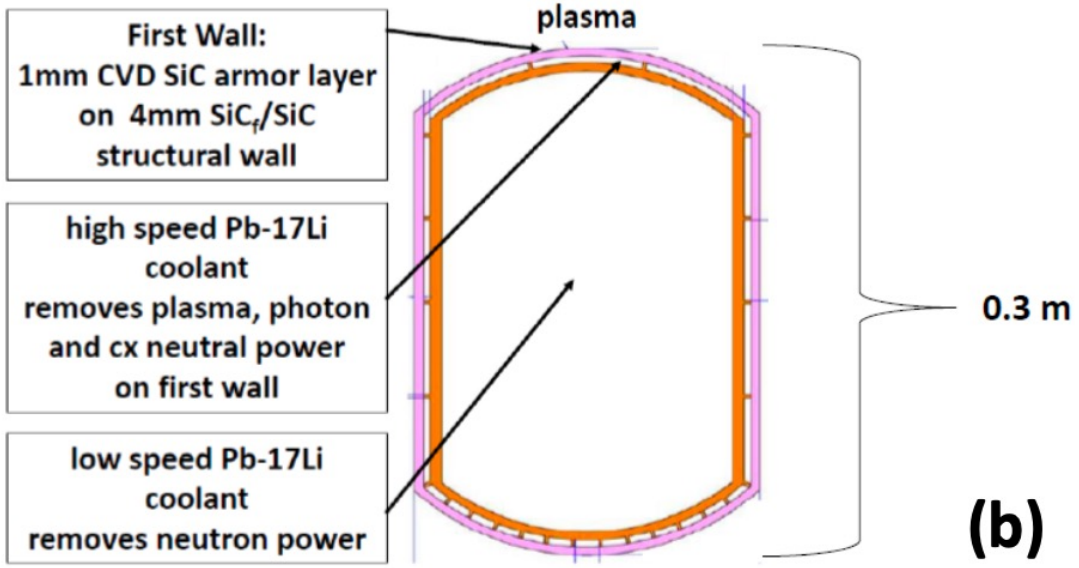
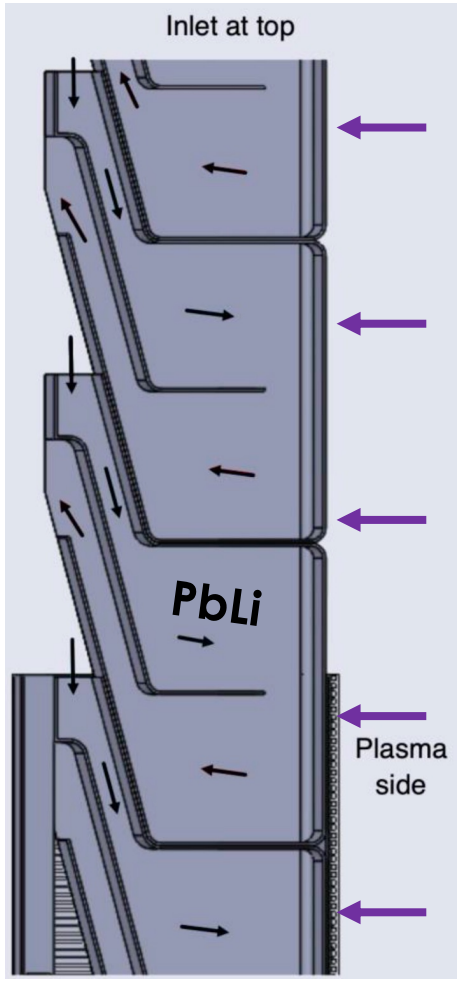


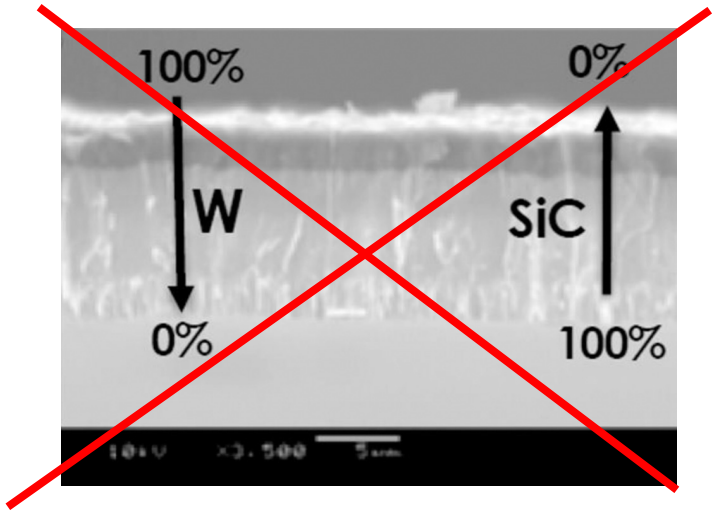
Raffray et al., FED (2006)



Tillack FED 2022

GAMBL - All SiC with W PFC

Ditch the W and make it all SiC!



(Compositionally graded W/SiC materials is extremely impressive and awesome science and I am not staying stop researching it)

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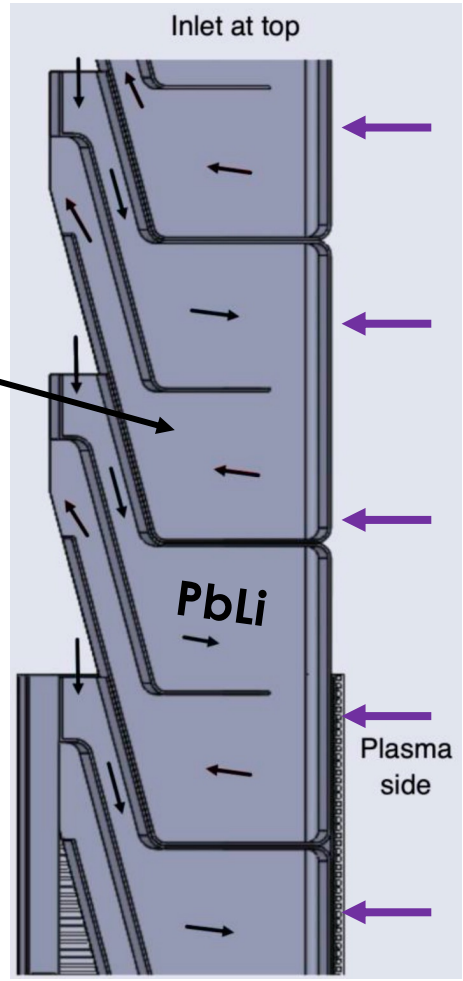
SiC walls could simplify blanket designs

Coolant already > 500 C… synergy opportunity for hot walls?



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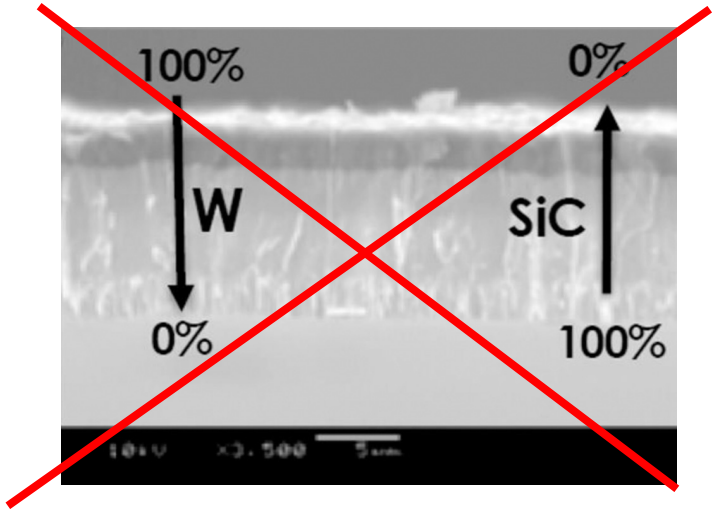

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